Development And Evaluation Of The "Thinking With Logo" Curriculum

Judi Hunter, Theresa Kemp and Ian Hyslop

Alberta Education

Alberta
EDUCATION

87-04846/

DEVELOPMENT AND EVALUATION OF THE "THINKING WITH LOGO" CURRICULUM

Judi Hunter, Theresa Kemp and Ian Hyslop*

Area 2 E.O.F. Computer Project

Calgary Board of Education

Under Contract to Alberta Education

Edmonton, Alberta

January, 1987

*Project leaders responsible for development of and research pertaining to this curriculum.

Report prepared by Cheryl Missiuna.

"The views and recommendations expressed in this report are those of the researchers and not necessarily those of Alberta Education."

ACKNOWLEDGMENTS

The authors are indebted to Sandra Pace and associates for their assistance in the development and evaluation of this project. They would also like to acknowledge the influence of the works and theories of Reuven Feuerstein on this curriculum.

Development of the curriculum reported herein was supported in part by the Calgary Board of Education, the Alberta Ministry of Education and the Canadian Centre for Learning Systems. The authors are grateful for the support provided by these agencies.

ABSTRACT

The goal of the project is to build a curriculum for the transfer of problem solving skills from the computer programming environment to the real world. The philosophy for the development of the curriculum will be the theory of Structured Cognitive Modifiability by Dr. Reuven Feuerstein. The project will attempt to prove the computer provides a medium for the learning of cognitive skills that are necessary for problem solving. The application of these skills from the programming environment to real world situations is dependent on a methodology that specifically addresses how to teach for this transfer.

TABLE OF CONTENTS

	Page
Introduction	1
Theoretical Rationale	3
Development of the "Thinking with LOGO" Curriculum	11
Description of the Curriculum	13
Evaluation of the "Thinking with LOGO" Curriculum	17
Table 1	19
Table 2	21
Table 3	22
Table 4	23
Table 5	24
Figure 1	21
Figure 2	22
Figure 3	23
Figure 4	25
Limitations of the Study	28
Recommendations for Future Research	29
Summary	30
Bibliography	31

INTRODUCTION

During the past few years, educators have begun to place increasing emphasis on the importance of developing thinking and problem-solving skills in children (Bransford & Stein, 1984; Nickerson, 1984; Dale, 1983; Beyer, 1984; Alberta Education, 1982). A complete educational program is now felt to encompass the teaching of approaches to problem-solving, critical thinking, inquiry processes and many other higher level cognitive skills. The introduction of computer programming and the teaching of a computer language have frequently been proposed as effective vehicles for developing problem-solving abilities in young children. (Clements, 1983). Computer programming is certainly an exciting and challenging environment for both teachers and students yet the cognitive benefits of learning to program have been largely unsubstantiated (Land & Turner, 1985). To date, many questions remain unanswered regarding the specific effects of learning to program a computer on children's cognition (Clements & Gullo, 1984).

Papert (1980), one of the developers of the computer programming language LOGO, has proposed that the experience of learning LOGO will facilitate the development of skills and powerful ideas which will be generally applicable in problem-solving situations. Studies throughout North America have challenged this statement by concentrating on one relevant question: are the problem-solving skills learned in LOGO able to be transferred to other domains? Evidence has been conflicting but the provisional answer appears to be that the "discovery learning" LOGO experience is insufficient to produce generalizable problem-solving skill development in children. It appears that a structured methodology is required wherein teachers "make more explicit the links between problem-solving in the context of programming and problem-solving in other contexts" (Land & Turner, 1985; p. 7). It is clear that a curriculum is needed which will utilize the beneficial aspects of the LOGO experience but which will emphasize the development of generalizable cognitive skills. It was the belief of these researchers that the teaching of a computer language could indeed promote problem-solving and develop thinking skills provided that specific

cognitive skills were identified and taught and that provision was made for the teacher to ensure transfer of learned skills to other domains.

The methodology used both to delineate the problem-solving skills and to introduce the programming language appeared to be a critical variable. Feuerstein, Rand, Hoffman and Miller's (1980) Instrumental Enrichment program identifies cognitive functions which can be taught and developed: this program was felt to provide a suitable model for the development of a thinking skills curriculum.

The curriculum which was developed, "Thinking with LOGO", encompasses Feuerstein's theory of structural cognitive modifiability (see Feuerstein 1979; Feuerstein et al. 1980; Feuerstein, Miller, Hoffman, Rand, Mintzker & Jensen, 1981; etc.) while using LOGO as the vehicle for the teaching of thinking skills. It was believed that every elementary classroom teacher could teach computer and thinking skills in the regular classroom; thus, emphasis has been placed upon the development of a program which is accessible to all teachers following minimal training. Six units, one for each grade in elementary school, were conceptualized. Four units have been developed and the remaining two units will be completed during 1987.

Throughout the "Thinking with LOGO" curriculum, the sequential development of problem-solving strategies has been emphasized and the teaching of computer skills has been kept to a minimum. The cognitive skills and metacognitive strategies which provide direction for the curriculum are felt to be educational components essential for helping children become independent learners.

The remainder of this paper will review the theoretical underpinnings of this curriculum and will outline the course of development and present format of the units. A pilot study undertaken to validate the effectiveness of this curriculum will also be described.

THEORETICAL RATIONALE

In order to achieve internal consistency, it is important that any curriculum be derived from a clear theoretical base. The "Thinking with LOGO" curriculum was developed from a conceptual structure that has three essential components:

1) a belief that learning to program a computer can be a potentially useful tool for the development of problem-solving abilities in children; 2) a set of concepts regarding the importance and necessity of ensuring the transfer and generalization of learned skills; 3) the concept of cognitive modifiability and the theory of mediated learning.

Computer Programming and LOGO

Microcomputers can be utilized for a multitude of purposes. In the educational field, three primary applications have been proposed (adapted from Delclos, Littlefield & Bransford, 1985):

1) Computer as Tutor

   Commonly referred to as computer-assisted instruction (CAI), the computer serves as a drill and practice machine. One of the major advantages of this approach is the ability to individualize learning for each child

2) Computer as Tool

   As a tool, a computer can assist its user to accomplish a given task more efficiently. Word processing is perhaps the most common example of this usage.

3) Computer as Tutee

   In this application, the student assumes a much more active role in learning to program the computer to achieve a specific purpose. He must learn to communicate with the computer, to identify a problem or goal, to plan a strategy, to implement that plan and then to evaluate the results. It is this usage of computers that is felt to foster problem-solving abilities in children.

Educators have shown increasing interest in this latter application of the computer as a learning tool controlled by students. I t appears logical that, by learning to program the computer, students would become more aware of their own problem-solving processes (Kantowski, 1983). In the search for a suitable programming language for children, educators around the world have become aware of the computer language LOGO. Originally developed by Papert (1980) and associates, LOGO use in schools has grown rapidly during the past five years (Nolan & Ryba, 1985).

Logo is a graphics-oriented structured language in which children learn to command a "turtle" to move around on the screen in order to create designs (Krasnor & Mitterer, 1984). The underlying philosophy of LOGO outlined by Papert (1980) has its roots in the Piagetian psychology of free exploration or "discovery learning". The thinking processes which Papert feels can be developed through LOGO are reviewed by Nolan and Ryba (1985). These include:

1) exploration - including the processes of coding, experimenting, predicting, hypothesizing and model-building;
2) procedural thinking - the processes of analyzing and planning in order to solve problems;
3) debugging - the process of learning to identify and correct mistakes.

Papert further proposes that the LOGO experience will introduce a child to powerful ideas including the concepts of hierarchical organization, planning and "some of the deepest ideas from science, from mathematics, and from the art of intellectual model building" (p. 5). This, in turn, is felt to lead to change in the way other learning takes place.

The high expectations raised by LOGO have led to much educational research which has, recently, begun to challenge some of Papert's claims. By far, the most prevalent concern documented by researchers is the inability of children who have used LOGO to transfer any of their problem-solving abilities to other situations (Krasnor & Mitterer, 1984; Delclos, et al. 1985;

Euchner, 1983; review of 16 studies in Land & Turner, 1985).

It would seem that learning LOGO in a free exploration environment does not result in generally improved planning and problem-solving skills; however, this does not imply that LOGO is not a useful tool for the learning of problem-solving skills. The difficulty appears to lie in the generalization of these skills to other contexts. Literature on generalization has repeatedly suggested that "no content, standing alone, can spontaneously produce generalizable learning" (Delclos et al. 1985 p. 154). It thus becomes important to consider the specific factors which are necessary for the generalization of problem-solving skills.

Transfer and Generalization of Thinking Skills

Generalization refers to the application of a learned strategy to a significantly altered situation in which both the demands of the task and the materials have changed (Blackman & Lin. 1984). As such, it is an extremely complex process in which the child must interpret the present problem, perceive and identify a relationship between the new situation and the old, and then selectively apply the problem-solving skills which he has learned (Rogogg & Mistry, 1985). Breakdown of skill generalization can occur at any stage but, most commonly, is felt to occur at the level of perceiving the relationship between events. In other words, the child has learned the problem-solving skills in one context but fails to recognize their applicability in a new learning situation.

Extensive research in the area of training for generalization has led to the identification of specific factors which appear to be essential to ensure the transfer of skills: each of these will be discussed in terms of generalization from LOGO to other problem-solving contexts.

1) Transfer between problem-solving domains requires that some of the specific processes used in the tasks be highly similar. The steps involved in designing a computer program are actually quite similar to those utilized in most problem-solving processes, therefore, theoretically, this requirement has been met. The difficulty

with the LOGO experience lies in the fact that the similarities may only be present at a very abstract level, not readily perceived by the students (Krasnor & Mitterer, 1984).

2) A child must recognize that a new problem is similar to one which he has already encountered. This requirement is closely related to the first but involves the additional recognition of the role of the child as an active organism who must perceive the relationship (Campione & Brown, 1984). Numerous examples have been described in the literature of children failing to transfer spontaneously the knowledge of LOGO procedures, even to very similar problems within the same instructional context (eg. Delclos et. al. 1985). In order for generalization to occur, it seems that learners must either be encouraged to state a general rule or else receive explicit instruction in the general applicability of a principle (Brown & Campione, 1981; Brown, Bransford, Ferrara & Campione, 1983).

3) Transfer may depend upon the completeness of the original learning and on exposure to a variety of situations in which the problem-solving skills may be useful (Krasnor & Mitterer, 1984). With respect to this requirement, two problems may arise using the traditional approach to LOGO. LOGO instruction is often relatively short-term; thus; mastery and proficiency even of the programming fundamentals may be insufficient to ensure the application of these analyses to other problems. Secondly, the learning of LOGO often occurs within a narrow context with the focus entirely on turtle graphics (eg. see Calgary LOGO Source Book). Without the explicit instruction or rule generalization outlined above, transfer of skills is unlikely to occur.

In summary, there appear to be a number of theoretical reasons to explain the lack of generalization of problem-solving skills that has been observed with LOGO. In a review of the research on the generalizability of LOGO learning, Krasnor and Mitterer (1984) were forced to

conclude that "there is as yet no good evidence that any of the powerful ideas [LOGO] generalize to other domains" (p. 137).

Given the similarity of approaches used in LOGO to the generally accepted steps in problem-solving, it would seem that the generalization of learned skills should be possible. The discovery-oriented approaches of the LOGO experience may not provide children with the explicit instruction which is needed for general problem-solving. A combination of LOGO content with an approach which stresses the development of thinking skills would seem to be a novel and potentially powerful tool.

Cognitive Modifiability and Mediated Learning

Some of the difficulties inherent in the generalization of thinking skills have been addressed by Dr. Reuven Feuerstein in the development of his concept of structural cognitive modifiability (see Feuerstein et al., 1980; 1981). In this theory, generalization is emphasized as an integral part of the learning process. Feuerstein (1979) believes that, in order to learn effectively, a child must become able to organize and interpret information in terms of general principles and strategies.

Feuerstein's theories are a challenge to, and yet a natural extension of the developmental concepts of Piaget. Feuerstein suggests that an individual's cognitive structure is continually undergoing modification as a result of two interactive types of learning. The first, as described by Piaget, results from the child's direct encounters with stimuli from the environment. This theory of learning serves as the basis for discovery learning approaches including the traditional exploratory emphasis of LOGO. The second modality of learning postulated by Feuerstein is termed "mediated learning experience". Feuerstein feels that an essential element of learning is the presence of an individual who interposes himself between the child and his experiences with the environment. This mediating adult organizes and transforms the stimuli which the child encounters so that the child is able to perceive the environment in a more meaningful way (Feuerstein, 1981). The intent of a mediated learning experience is to improve the child's ability to recognize and use the appropriate cognitive skills required by a task (Feuerstein, 1970). The child is also taught content,

principles and strategies which are necessary for successful performance and is helped to perceive relationships among tasks or situations. This approach should logically facilitate the generalization of cognitive skills which have been learned to related situations.

The provision of mediation is not contingent upon the content around which it takes place (Feuerstein, 1979). Certain criteria are essential, however, in order for an interaction to be truly mediational (criteria adapted from Feuerstein & Hoffman, 1982; Klein & Feuerstein, 1985):

1) Intentionality: The adult must have a specific purpose or goal for that learning situation and must demonstrate this through his actions or words.

2) Transcendence: The mediated learning experience must transcend the immediate needs of that situation. The adult must transmit to the child an understanding of the principles or strategies that will be helpful in other situations. He must also help the child to understand the usefulness and generalized-meaning of the new learning and to relate it to other contexts.
3) Meaning: The meaning or purpose of the interaction must be clearly conveyed to the child.

Through mediated learning experience, then, it is believed that children learn how to generalize experiences, to induce rules, to know when rules should not apply, to perceive relationships and to think abstractly (Haywood, Burns, Arbitman-Smith & Delclos, 1984). The theory of mediated learning experiences is the foundation of Feuerstein's belief that children's cognitive abilities can be modified (Feuerstein et al. 1980). This theory has culminated in the development of Instrumental Enrichment, a curriculum designed to improve each child's ability to approach and benefit from academic and life experiences.

Instrumental Enrichment (IE) consists of sixteen instruments or units which are comprised of paper and pencil exercises. Each instrument focuses on a particular set of cognitive functions such

as those required for comparative behavior, spatial orientation, etc. Since the content of "Thinking with LOGO" differs so considerably from the IE lessons, only the structure of the IE lessons will be described further.

The IE lessons are structured in order that teachers may teach systematic approaches to problem-solving: the processes and strategies used by the students are emphasized rather than the actual task. Each lesson begins with an introduction during which time the teacher helps the students to define the problems and objectives of the lesson. Any concepts or vocabulary required for the task are also taught. Students then work independently on the exercise. The teacher offers assistance and encouragement, reinforces skills and prevents the repetition of errors, as required. The class as a whole is then involved in a discussion of the problems encountered and their various solutions. The teacher guides the students to analyze difficulties, to explore alternative solutions, and ultimately, to derive a cognitive principle or strategy which may be helpful in similar situations. At the end of the lesson, students are prompted to form bridges or generalizations to other problem situations where this type of strategy might apply. The teacher may summarize the lesson but the student should also be able to state clearly what was learned (described in detail in Feuerstein et al. 1980).

Throughout the lesson, a mediational teaching style is used to assist students to focus on the problem, to search systematically for information, to compare, to develop insight, to plan, to respond carefully and to evaluate their responses. This mediational style is critical to the success of the program. (Samuels, 1986).

The Instrumental Enrichment curriculum has served as the framework for the development of the "Thinking with LOGO" units. Through the use of this format it is felt that many of the difficulties with generalization of thinking skills will be addressed. Mediated learning, with its emphasis on metacognitive strategies and bridging to other situations, is felt to be the ideal method for teaching computer programming with the ultimate aim of developing problem-solving abilities in children.

The objective of this curriculum will be to combine the exciting and motivating environment

of LOGO with the principles of mediated learning experience in order to teach problem-solving skills that will be lasting and generalizable.

DEVELOPMENT OF THE "THINKING WITH LOGO" CURRICULUM

The concepts of the Instrumental Enrichment program and the framework of the lessons provided the model for the development of this curriculum. One important distinction should be noted: whereas Instrumental Enrichment is designed as a 'content-free' curriculum, the "Thinking with LOGO" curriculum may be considered to be 'content-loaded'. The rationale for this difference was based on three factors. Firstly, consideration of previous failure experience isn't a paramount concern with regular education learners. Secondly, LOGO is a developmentally appropriate programming language that is likely to be novel to both teachers and students (ie. most teachers will not have pre-established ideas regarding the best instructional methods for delivery of the content). Finally, the graphics capabilities of LOGO provide an exciting environment whereby a child can experiment with the spatial concepts and relationships felt to be prerequisite for higher order problem-solving skills (Feuerstein et al. 1980).

In the development of the curriculum, each unit was designed to attain specific cognitive objectives. The sequential development of skills and the rationale for these cognitive objectives have been outlined at the beginning of each unit in a brief concept paper. Each lesson within the unit identifies a cognitive goal as its focal point. This is then translated into a statement of a metacognitive strategy which the teacher assists the students to derive. The pencil and paper exercises and computer activities introduced throughout the lesson are designed to highlight the metacognitive strategy and to provide an opportunity for it to be applied. As an example, the cognitive goal for the day might be to introduce the concept of inductive reasoning. The related metacognitive principle, which is stated in practical terms, would be: "The discovery of the relationship between events allows us to form a rule".

The teacher utilizes a mediational style of teaching in order to lead the children to an awareness of the problem, to derive the metacognitive strategy and then to form bridges to other examples of its application in daily living situations. Ideally, this strategy will be spontaneously

carried over by the teacher and reinforced in other parts of the curriculum.

Teachers who will implement a thinking skills curriculum must be carefully trained. In order to validate the effectiveness of the curriculum, an extensive pilot project was undertaken at the Grade 5 level and a unit was also introduced at the Grade 3 level (described in detail in Evaluation section). It was the belief of these researchers that computer specialists were not required but, instead, that regular classroom teachers would be able to utilize this curriculum successfully. As a result, all teachers planning to use this curriculum were relieved of classroom duties and attended a 2 - 3 day workshop. The first day consisted of a presentation of Feuerstein's theory of cognitive modifiability, an outline of the critical components of a mediated learning experience and the identification of cognitive functions and skills which could be taught in the classroom. During the next 2 days, the units were introduced, presented and the mediational teaching style was modelled. One half day was allocated for presentation of each unit: most teachers only attended the day on which the unit for their grade was covered.

Following the workshop, project leaders visited the classrooms and modelled and/or monitored the implementation of the units. At the end of the pilot phase of implementation, feedback was solicited from the teachers regarding specifics of the lessons as well as their general comfort level with the curriculum. These comments will be used in the ongoing reviews of the curriculum.

At this point, units for Grades 1,2,3, and 5 have been developed and the Grade 3 and 5 units have been tested. Units 4 and 6 are still in the process of being created.

DESCRIPTION OF THE CURRICULUM

The curriculum, as discussed previously, is still undergoing development and revision. The completed curriculum will be comprised of six units, one to be taught at each grade level.

Orientation in Space	Grade 1
Organization	Grade 2
Comparisons	Grade 3
Analytic Perception	Grade 4
Induction	Grade 5
Deduction	Grade 6

In this section, the units which have been developed will be briefly described and a typical lesson plan will be outlined.

At the beginning of each unit, the teacher is provided with an overview of the cognitive goals which will be achieved, the cognitive functions which will be addressed and the mental operations which will be emphasized. The LOGO content covered within the unit is clearly specified and, as well, the required vocabulary and materials are outlined. Within the unit, the same information is provided in more detail for each individual lesson. Each unit contains from 14 to 21 individual lessons. A lesson may be completed in one class period or may be taught over a number of classes depending upon the level of the children.

The following is a description of the cognitive goals and objectives which are developed throughout the curriculum.

Objectives in Space

In the first unit, children are introduced to the use of systematic search strategies as a method of exploring their world. Universal principles such as problem definition, labelling,

organization of information, planning and recording are presented and developed. The children's ability to use and internalize a stable, personal reference system (e.g. right, left, up, down) is emphasized throughout.

Organization

The second unit elaborates on the concepts introduced in Grade 1 but emphasizes the organization of information in order to develop a plan. The children are taught basic problem solving strategies including: identifying the whole problem, organizing information, subdividing the problem into manageable components, making a plan, attempting a solution and then evaluating the success of their response.

Comparison

Comparative behavior is a skill which is developed and refined in this unit. Children learn to differentiate relevant from irrelevant parameters of comparison and to compare objects on the basis of actual or inferred similarities and differences. Class inclusion is stressed throughout and comparative decisions are encouraged which are based upon clear, accurate definitions of the relationships between categories.

Analytic Perception

(in progress)

Induction

By Grade 5, students will have learned a systematic method of exploring evidence, organizing and comparing data, and will be ready to develop strategies for identifying patterns and discerning relationships among objects or events. This process of induction and its role within the scientific method is highlighted in this unit.

Deduction

(in progress)

A Typical Lesson

Each lesson has four essential components: (1) introduction; (2) independent student activity; (3) discussion and summary; (4) statement of metacognitive strategy and generalization. Ideas are provided in a section entitled "Lesson Elaboration" regarding the content to be covered in each component.

Introduction. During the introduction the teacher uses a mediational teaching style to help the children explore and analyze the task for that day; generally, an activity sheet would serve as the focus of their attention. The teacher encourages the children to explore the activity systematically, and to define the problem clearly. Possible strategies which might be useful for solving the problem are explored and concensus is reached regarding the approach which the children will attempt. Any vocabulary or computer skills required for performance of the task are taught. The students may also decide how they will judge their solution once it has been reached. Difficulties which might be encountered are anticipated by the class as a whole and strategies for correction are discussed. By the end of the introduction, each student should have a clear understanding of the problem, some strategies for implementation and ways to review and evaluate their solution.

Student Activity. The student proceeds to perform the designated activity independently or in a small group. A lesson may include a paper and pencil exercise, a "hands on" computer exercise, or a combination of the above. The teacher circulates in order to guide the learning experience and to prevent frustration or the practicing of errors.

Discussion/Summary. .The class reconvenes to discuss their results and, in the case of differing responses, to compare the solutions which have been reached. The teacher facilitates the constructive exploration of all divergent strategies. The focus of this discussion is always on the

processes used to derive a solution and not on the correctness of the answer. Incorrect responses may instead prompt a discussion of how one is able to check an answer or how to "debug" one's programs.

Derivation of Metacognitive Principle. The teacher eventually brings the discussion to its logical conclusion in the stating of a "rule" which the children have learned from the lesson. This rule should not be content-bound but should be a statement of a general principle which might apply in any similar situation. Effort is directed toward ensuring that each child comprehends and can state the principle which has been learned.

The metacognitive principle is then immediately "bridged" to daily life situations. The teacher questions the children and tries to elicit the bridging examples from their own experiences. For example, one metacognitive principle was stated: "If our data is organized, it helps us to see patterns". Logical generalizations which are within the realm of each child's experience might include multiplication tables, keeping track of the number of wins/losses of a sports team, keeping record of how the child spends his allowance, and so forth. The more examples which the children are able to generate, the more likely that the strategy will be recalled and generalized in another context. The teacher guides this discussion to ensure the applicability of each example to the principle which was learned.

Ideally, since this curriculum is carried out by regular classroom teachers, the bridging will occur naturally throughout all aspects of the school day. The children's active participation and the teacher's appropriate use of mediation are felt to be critical components for successful implementation of this curriculum.

The focus of the project leaders in the 1985-86 academic year has been upon the creation, development and refinement of the "Thinking with LOGO" curriculum. The preliminary evaluation of the curriculum which was undertaken will now be described.

EVALUATION OF THE "THINKING WITH LOGO" CURRICULUM

In order to evaluate the effectiveness of the "Thinking with LOGO" curriculum, a pilot project was undertaken in Area 2 from January to June, 1986. The purpose of this study was to ascertain whether a curriculum utilizing LOGO to develop problem solving skills would obtain greater cognitive growth than current approaches. This curriculum was systematically contrasted with traditional LOGO experiences and with a control classroom which did not utilize LOGO or mediated learning approaches.

Methodology

Six elementary schools within Area 2, Calgary Board of Education, were selected to participate in this study. Selection was based upon the interest and commitment of principals and staff, the staff's prior knowledge of LOGO and the availability of computer hardware. A quasi-experimental design was utilized since it was not possible to randomly assign students to the three intervention groups (Thinking with LOGO/Traditional LOGO/Control).

Subjects

For the purpose of this pilot project, only students in Grades 3 and 5 were utilized. The two units for these grades were felt to be thoroughly developed and the children of sufficient maturity to be able to undergo group and individual testing. Table 1 contains a summary of the final school and numbers of children by group assignment.

Procedure

In January, 1986, the Canadian Cognitive Abilities Test (CCAT: Version 3; Form A) was administered as a pretest to all of the children involved in this study. All of the Verbal and Non-Verbal tests plus selected subtests from the Quantitative sections were given at the Grade 5

level. Selected subtests from the Verbal section only were administered at the Grade 3 level.

All teachers involved in the research had previous experience with LOGO, and all but one teacher were grade generalists. Inservice training was conducted (as described in the Development section) and the curricula were then implemented twice weekly for a period of 12 weeks. A brief summary of the distinction between the three approaches is provided below.

"Thinking with LOGO" Curriculum

Teachers utilized the curriculum which had been developed for that grade. All teachers had received inservice training in the use of LOGO to facilitate the learning of problem solving skills and had been introduced to Feuerstein's concepts of mediated learning. Support and modelling was provided in the classroom by the project leaders on a perceived need basis (ranged from 3 - 15 hours).

Traditional LOGO Curriculum

Teachers who utilized this approach to LOGO were already familiar with the computer language. These teachers received an outline of the specific LOGO skills which were to be covered within the treatment period. A copy of the Alberta Ministry of Education recommendations for the teaching of problem solving within the mathematics curriculum was also sent to teachers. The teacher who taught 2 classes at Colonel Scott Elementary School taught all of the programming classes in Grades 4,5, and 6.

Control Group

The teacher of this class did not receive any inservice training nor was LOGO utilized in her classroom. The teacher was permitted to continue with other types of computer or problem solving activities which normally would have been conducted as part of her curriculum.

TABLE 1

Subjects: Group Assignment, Location and Numbers

Grade 5

"Thinking with LOGO" Curriculum

Schools:	Alex Munro	24
	North Haven	26
	Vista Heights	26
		N = 76

Traditional LOGO Curriculum

Schools:	Rundle	27
	Col. Scott	24
	Col. Scott	27
		N = 78

Control Group

School: Cambrian Heights N = 23

Grade 3

"Thinking with LOGO" Curriculum N = 27

Traditional LOGO Curriculum

School: Rundle N = 27

Results

The results of the large group testing on all children were analyzed with the assistance of staff from the Calgary Board of Education. Due to the quasi-experimental design of the pilot project, the statistical assumptions of random assignment and normality of the sample were unable to be met. The assumption of homogeneity of variance was met as determined by the lack of any significant difference on the pretest scores and, therefore, parametric statistics were applied. The results, however, must be interpreted in light of these limitations.

Pre and post-test data from the CCAT were utilized. If this data was not available for any given student, that student was dropped from the analysis. The numbers, by group assignment, of students whose data was analyzed are summarized in Table 2. Pretest scores for the three groups were found to be statistically equivalent ($p.<05$) on all tests; thus, the results reported are for pre to post-test gain scores. In all cases, an analysis of variance was performed initially: t-tests were only utilized if a significant effect was found.

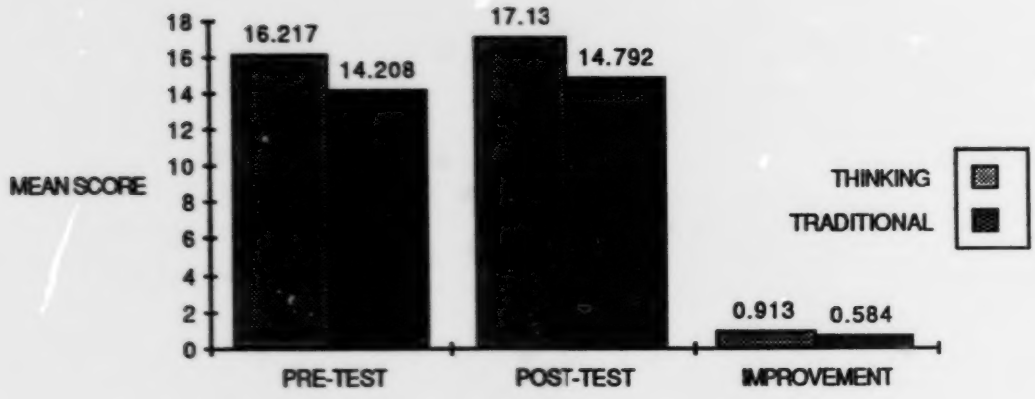
Grade 3

Mean improvements were found for both the "Thinking with LOGO" and the traditional LOGO groups on the selected verbal subtests of the CCAT: significant differences in the magnitude of the improvements were not obtained.

Table 2: Size of Groups Analysed with Mean Improvement

TABLE 2		
GROUP	SAMPLE SIZE	MEAN IMPROVEMENTS
Thinking with LOGO	n = 23	0.913
Traditional LOGO	n = 24	0.584
F = 0.065		

Figure 1: Grade 3 - Mean Score Data on Verbal Test (Table 2)



Grade 5

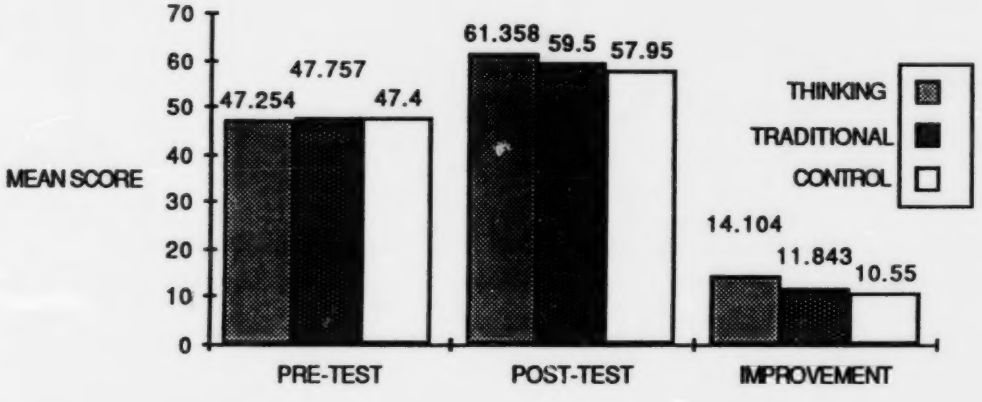
Verbal

Mean improvement were found for all 3 groups on the verbal subtests of the CCAT; significant differences in the magnitude of the improvement were not obtained.

TABLE 3

	Thinking with LOGO	Traditional LOGO	Control	F
ANOVA	n = 67	n = 70	n = 20	1.858
Pretest	47.254	47.757	47.4	
Post-test	61.358	59.6	57.95	
Mean Improvement	14.104	11.843	10.55	

Figure 2: Grade 5 Mean Score Data, Verbal Test (Table 3)

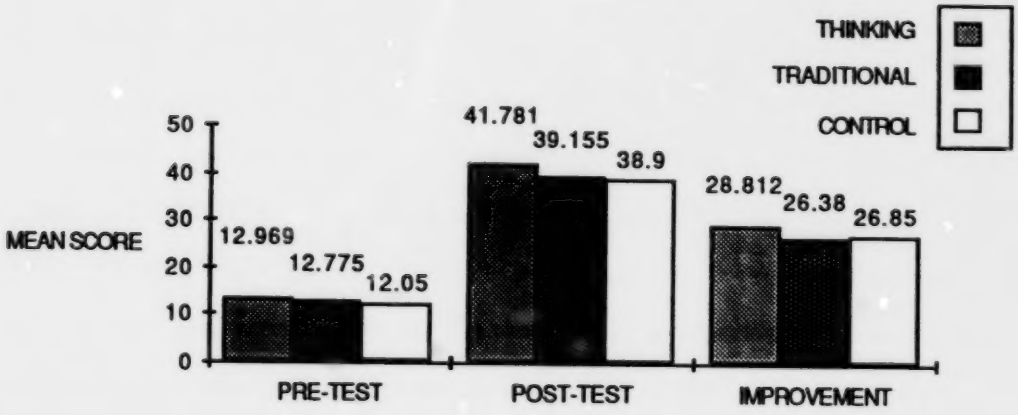


Quantitative

No substantial pre to post-test change was noted for either group.

TABLE 4				
	Thinking with LOGO	Traditional LOGO	Control	F
ANOVA	n = 64	n = 71	n = 20	1.145
Pretest	12.969	12.775	12.05	
Post-test	41.781	39.155	38.9	
Mean Improvement	28.812	26.38	26.85	

Figure 3: Grade 5 Mean Score Data Quantitative Test (Table 4).



Non-Verbal

Analysis of variance indicated that the slight improvements noted in the non-verbal section were not equal for all groups.

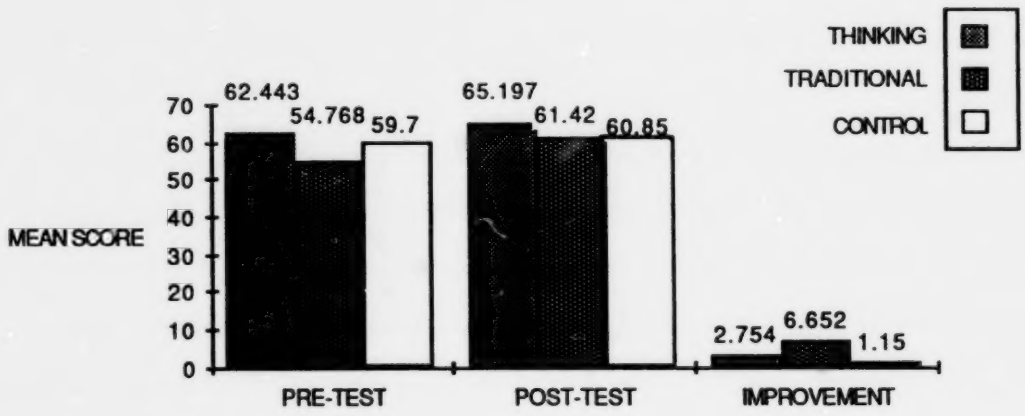
($F(2,147) = 4.108$; $p.<.05$). Subsequent t-tests for independent samples were conducted to identify the sources of significance identified by the analysis of variance. Significant t's (2.1676 and 2.3885) were obtained for the comparisons between the Thinking with LOGO and the Traditional LOGO groups and the Traditional LOGO and the Control groups. In both cases the superior performance was by the Traditional LOGO group.

TABLE 5

	Thinking with LOGO	Traditional LOGO	Control	F
ANOVA	n = 61	n = 69	n = 20	4.108*
Pretest	62.443	54.768	59.7	
Post-test	65.197	61.42	60.85	
Mean Improvement	2.754	6.652	1.15	

*p <.05

Figure 4: Grade 5 Mean Score Data Non-Verbal Test (Table 5).



Discussion

The objective of the pilot was to evaluate the effectiveness of the "Thinking with LOGO" curriculum in developing problem solving skills in young children. The failure of this study to demonstrate measurable differences on the CCAT in no way suggests that the curriculum was ineffectual. The major explanation of this finding lies in the fact that intervention was implemented for an extremely short period of time. It is highly unlikely that any durable cognitive change, as is described by Feuerstein, could be achieved this quickly. Changes which might have been observed within such a short time would more likely be identified during individual testing which focused on a child's independent approaches to problem solving tasks. Unfortunately, comparative data is not available since the individual strategies testing was only conducted at the post-test.

Additional factors which must be considered involve the teachers and classrooms utilized in the study. The "Thinking with LOGO" teachers' lack of familiarity with a mediational teaching

style was certainly a hindrance, at least initially, to the effective implementation of the curriculum. Although all the teachers who taught LOGO were experienced LOGO teachers, two of the three Traditional LOGO classes were taught by one teacher. Although it is the belief of these researchers that this curriculum can be utilized by regular elementary teachers, the short duration of this project may have precluded a truer evaluation of its effect when administered by teachers comfortable with this approach.

Although the testing in this study involved six schools, an additional number of schools received the inservice and assistance in the delivery of the program to their students. A survey conducted in June indicated the majority of teachers who received the inservice package also felt comfortable with the "Thinking with LOGO" curriculum at their grade level and in addition, completed the "Thinking with LOGO" unit. This survey was given to 218 teachers in 11 schools, with a response rate of 74 percent. Teachers responded to the following questions (a check indicated it applied): I ...

have received inservice in LOGO programming

have received inservice in Thinking with LOGO

have completed one unit in LOGO programming

have completed one unit in Thinking with LOGO

feel comfortable about using the LOGO language

feel comfortable with Thinking with LOGO (at grade level).

Eight teachers indicated no inservice training but responded to other questions in the survey. The chart below excludes those teachers, and shows only the teachers who received inservice and responded to the other statements.

	Total "YES" Responses
LOGO INSERVICE	91
LOGO COMFORT	57
LOGO UNIT	40
THINKING WITH LOGO INSERVICE	53
THINKING WITH LOGO COMFORT	40
THINKING WITH LOGO UNIT	29
	n = 210

The percentage of teachers that felt comfortable following inservice was 80% for the "Thinking with LOGO" group compared to 63% for the Traditional LOGO group. Similarily, the percentage of teachers using LOGO in the classroom following inservice was 55% for the "Thinking with LOGO" group compared to 44% for the Traditional LOGO group. The difference in the results between the Traditional LOGO and "Thinking with LOGO" may be due in part to the length of time between the inservice and the introduction of the program to the classroom. The majority of teachers involved with the "Thinking with LOGO" program delivered the program within two weeks of receiving the inservice. In addition, consultative and teaching support from the researchers was available. This kind of support is rarely available to teachers through traditional inservice courses.

LIMITATIONS OF THE STUDY

1) One of the major limitations of this research was that children were not able to be randomly assigned to intervention groups. The manner in which classrooms were selected (eg. prior staff knowledge of LOGO) may certainly have biased the results. The selection of teachers for the control and traditional approaches was a limitation.
2) The data analysis considered only the results of group mean differences on total categories of subtests. Individual differences in children's qualitative approaches to problem solving are extremely difficult to measure but would merit serious considerations for future study in this area.
3) All of the children utilized in the study attended schools in Area 2 of the Calgary Board of Education. The sample may not be representative of elementary school children generally. Additional subject bias may have been present in the use of children in the "Traditional LOGO" group who had already been receiving computer training. Although effort was taken to ensure comparability of pretest scores on the CCAT, other variables (eg. age, sex, achievement scores) could not be controlled.
4) The same form of the CCAT was used for the pretest and post-test. Since the Calgary Board of Education uses the parallel form of the CCAT for system testing, an alternate test was not available.

RECOMMENDATIONS FOR FUTURE RESEARCH

Given the interesting trends obtained by this pilot project, it is recommended that further research be conducted. The effectiveness of this curriculum in developing problem solving skills and in producing cognitive benefits should be undertaken with consideration given to the following study modifications:

1) The classroom teacher responsible for implementation should receive thorough training as outlined in this report. Provision of continued support should be available on an individual basis as required.
2) The unit appropriate to that grade level should be implemented twice weekly for the duration of the unit.
3) Pretesting and post-testing should include measures of problem solving and reasoning abilities in verbal, quantitative and visual-spatial areas. Consideration should also be given to instruments which could measure shifts in self-esteem and locus of control.
4) Comparison with other approaches (eg. free exploration LOGO) should be carried out in a systematic manner involving either random assignment or pretesting for compatibility of experimental groups.
5) Analysis of data should be sufficiently detailed to give consideration to the progress and individual differences of learners, and should not rely solly on group-based designs.
6) Given the nature of this curriculum (eg. spans 6 grades), it is felt that a longitudinal study should be undertaken to evaluate its effectiveness after a minimum of 3 years implementation. In order to be comprehensive, it is hoped that a study of this magnitude would consider the above recommendations and would also measure the effect of age, sex, ability groupings, parental attitude toward computers etc.

SUMMARY

This report reviewed the development and evaluation of a new curriculum entitled "Thinking with LOGO". This curriculum utilizes the beneficial aspects of the LOGO computer experience while emphasizing the sequential development of problem solving strategies. The materials which have been developed are based upon a solid theoretical foundation that supports the integration of computer technology to enhance the learning of problem solving skills. The format of the curriculum plus the use of mediational teaching style are felt to be essential components in order to teach thinking skills that will be lasting and generalizable.

During the 1985-86 academic year, the curriculum was developed, inservice training provided to a selected group of teachers, and a pilot project was undertaken. A total of 231 students in Grades 3 and 5 were involved in this study. The preliminary results did not offer substantive support for the curriculum, however, the short duration of intervention, the teachers' lack of familiarity with mediation and other logistical factors have been proposed as possible explanations.

"Thinking with LOGO" has proven viable as an alternative methodology for the teaching of problem solving to elementary school children. With minimal inservice training, the curriculum was able to be implemented by regular teachers. The length of time for this to become an effective means for producing cognitive change in children has yet to be determined.

The curriculum is now in the process of being completed and refined. It is the firm belief of the project team that the "Thinking with LOGO" curriculum holds great potential for inducing generalizable problem-solving abilities in children. Given the limitations of the evaluation performed to date, it is the intent of these researchers to seek further support for a much more extensive evaluation of the curriculum in the 1987-88 academic year.

BIBLIOGRAPHY

Alberta Ministry of Education (1982). Program of studies for elementary school science and mathematics.

Beyer, B.K. (1984). Improving thinking skills - Defining the problem. Phi Delta Kappan, March, 486 - 490.

Blackman, L.S. & Lin, A. (1984). Generalization training in the educable mentally retarded: Intelligence and its educability revisited. In P. Brooks, R. Sperber, & C. McCauley (Eds.), Learning and cognition in the mentally retarded. Hillsdale, N.J.: Lawrence Erlbaum Associates Publishers.

Bransford, J.D., & Stein, B.S. (1984). The IDEAL problem solver: A guide for improving thinking, learning and creativity. N.Y.: W.H. Freeman & Co.

Brown, A., Bransford, J., Ferrara, R., & Campione, J. (1983). Learning, remembering and understanding. In J. Flavell & E. Markman (Eds.) Carmichael's manual of child psychology, Vol. 1, N.Y.: Wiley Press.

Brown, A., & Campione, J. (1981). Inducing flexible thinking: A problem of access. In M. Friedman, J. Das & N. O'Connor (Eds.). Intelligence and learning. N.Y.: Plenum Publishers.

Campione, J.C., & Brown, A.L. (1984) Learning ability and transfer propensity as sources of individual differences in intelligence. In P. Brooks, R. Sperber, & C. McCauley (Eds.). Learning and cognition in the mentally retarded. Hillsdale, N.J.: Lawrence Erlbaum Associates Publishers.

Clements, D.H. (1983). Programming, problem solving and practice. Arithmetic Teacher, December, 32 - 35.

Clements, D.H., & Gullo, D.F. (1984). Effects of computer programming on young children's cognition. Journal of Educational Psychology, 76(6), 1051 - 1058.

Delclos, V.R., Littlefield, J., & Bransford, J.D. (1985). Teaching thinking through LOGO: The importance of method. Roeper Review, 7(3), 153 - 156.

Euchner, C. (1983). Debate grows on LOGO's effect on thinking skills. Education Week, November, pp. 10, 15.

Feuerstein, R. (1970). A dynamic approach to the causation, prevention and alleviation of retarded performance. In H.C. Haywood (Ed.), Socio-cultural aspects of mental retardation. N.Y.: Meredith Corporation.

Feuerstein, R. (1979). Ontogeny of learning in man. In M.A. Brazier (Ed.), Brain mechanisms in memory and learning: From the single neuron to man. N.Y.: Raven Press.

Feuerstein, R. (1981). Mediated learning experience in the acquisition of kinesics. In B.L. Hoffer & R.N. St. Clair (Eds.), Developmental kinesics: The emerging paradigm. Baltimore: University Park Press.

Feuerstein, R., & Hoffman, M.B. (1982). Intergenerational conflict of rights: Cultural imposition and self-realization. Journal of the School of Education, 58 (1), 43 - 63.

Feuerstein, R., Miller, R., Hoffman, Y., Mintzker, Y., & Jensen, M.R. (1981). Cognitive modifiability in adolescence: Cognitive structure and the effects of intervention. The Journal of Special Education, 15(2), 269 - 287.

Feuerstein, R., Rand, Y., Hoffman, M.B. & Miller, R., (1980). Instrumental Enrichment: An Intervention program for cognitive modifiability. Baltimore: University Park Press.

Gooliaff, B., Savill, W., & Kemp, T. (date unknown). Calgary LOGO source book. Calgary: Media Services Group, Calgary Board of Education.

Haywood, H.C., Burns, M.S., Arbitman-Smith, R., & Delclos, V. (1984). Forward to fundamentals: Learning and the fourth R. In J.R. Newbrough & P.R. Dokecki (Eds.), Peabody Journal of Education,61, 16 - 36.

Kantowski, M.G. (1983). The microcomputer and problem solving. Arithmetic Teacher, February, pp. 20 - 21, 58 - 59.

Klein, P., & Feuerstein, R. (1985). Environmental variables and cognitive development. In S. Harel, & N.S. Anastasiow (Eds.), The at-risk infant: Psycho/socio/medical aspects. Baltimore: P.H. Brookes Publishing Co. Ltd.

Krasnor, L.R., & Mitterer, J.O. (1984). Logo and the development of general problem solving skills. The Alberta Journal of Educational Research,30(2), 133 - 144.

Land, M.L., & Turner, S.V. (1985). What are the effects of computer programming on cognitive skills? Paper presented at the Annual Meeting of the Association for Educational Data Systems, Toronto.

Nickerson, R.S. (1984). Kinds of thinking taught in current programs. Educational Leadership, September, 26 - 36.

Nolan, P., & Ryba, K. (1985). Assessing learning with LOGO. ICCE Monograph One. Massey University, Australia.

Papert, S. (1980). Mindstorms: Children, computers and powerful ideas. N.Y.: Basic Books.

Rogoff, B., & Mistry, J. (1985). Memory development in cultural context. In M. Pressley & C. J. Brainerd (Eds.), Cognitive learning and memory development in children: Progress in cognitive development research. N.Y.: Springer-Verlage Co.

Samuels, M. (1986). Instrumental Enrichment with learning disabled students. Paper presented at the International Association for Children with Learning Disabilities Meeting, New York.